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RESEARCH ANALYSIS CORPORATION

Cost-of-Research Index, 1920-1965

by
Helen S. Milton

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RESEARCH ANALYSIS CORPORATION

MCLEAN, VIRGINIA

FOREWORD

The cost-of-research index was introduced in 1960 by Ellis A. Johnson and Helen S. Milton in ORO-SP-142, "A Proposed Cost-of-Research Index." At the special request of the Office of the Chief of Research and Development, Department of the Army, the current updating of that study was undertaken. In addition to the previously reported data for the period 1920-1965, this paper presents minor revisions in the annual index numbers for the years 1951 through 1958 and current data for the years 1958 through 1965.

The data coverage on which this paper is based is virtually the same as in the earlier study. The variations result primarily from revisions in structure of individual cooperating organizations and shifts in emphasis within R&D programs. These aspects may be considered representative of developments in the R&D field. As in the previous study, the data are presented with minimum interpretation. The intent is to provide only that necessary for the understanding of the data.

Philip H. Lowry
Head, Combat Analysis Department

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CONTENTS

Foreword	iii
Acknowledgments	iv
Abstract	2
Cost-of-Research Index, 1920-1965	3
Participation of Organizations—Individual and Group Indexes— Cost-of-Research Index—R&D Dollars and Effort—Professional R&D Personnel by Sectors—"Theoretical" and "Development" R&D Costs—Equipment Costs—Professional Scientific Salaries— Index Trends, 1950-1965	
Summary	15
References	19
Figures	
1. Indexes of R&D Cost per Technical Man-Year for 17 Organizations, 1920-1965	4
2. Group Indexes of R&D Cost per Technical Man-Year, 1950-1965	6
3. Index of R&D Cost per Technical Man-Year, 1920-1965	7
4. US R&D Expenditures and Technical Effort, 1950-1965	8
5. Index of R&D Cost per Technical Man-Year and Consumer Price Index, 1920-1965	9
6. Indexes of R&D Cost per Technical Man-Year for Theory- Oriented and Development-Oriented Organizations, 1950-1965	12
7. R&D Salary Indexes according to Years from Graduation for Professional Nonsupervisory Personnel, 1950-1965, by Group	14
8. Index of Cost per Technical Man-Year, 1950-1965	16
9. Cost per Technical Man-Year: Relative Increases Based on Annual Percentage Increases	17
10. Cost per Technical Man-Year: Relative Increases Based on 3-Year Averages of Percentage Increases	17

Tables

1. Index of R&D Cost per Technical Man-Year Based on Data from 17 R&D Organizations, 1920-1965	7
2. R&D Scientific and Technical Personnel, by Group	10
3. Average Annual Increases in Salaries of Nonsupervisory R&D Scientific and Professional Personnel Classified by Years since Graduation	13

Cost-of-Research Index, 1920-1965

ABSTRACT

The cost-of-research index provides a measure of the cost of technical man-years supported by research and development (R&D) funds expended yearly in the US relative to effort—in contrast to dollars—that has been put forth in US R&D.

Although the annual US R&D dollar totals have increased from less than \$3 billion in 1950 to about \$22 billion in 1965, the actual man-years of technical effort indicated by the application of the cost-of-research index to the annual dollar totals increased at approximately one-half the rate of increase of funds expended.

During the past 5 years there has been an appreciable decline from the mid-1950's in the rate of increase in the technical-man-year costs. An almost comparable pattern is noted in 1960-1965 for salaries of R&D scientific and professional personnel.

Research and development is accomplished by the expenditure of manpower and dollars, and all approaches to planning and budgeting for R&D must be based on consideration of both. The cost-of-research index designed to determine the rates of change in costs per technical man-year should be updated and applied in such planning and budgeting on a recurring annual basis.

COST-OF-RESEARCH INDEX, 1920-1965

The importance to the American economy of research and development (R&D) costs, along with their growth trends over the past 4½ decades, is clearly indicated by the 1965 investment in R&D—almost \$2 billion a month. The annual total was some eight or nine times that of 1950 and 25 to 30 times that of 1940.¹⁻⁶ The funding level has doubled about every 6 years, but the question is: how fast has the actual R&D effort increased?

The initial objective of the cost-of-research index was to provide a measure of the cost of the technical man-years supported by the R&D funds expended yearly in the US relative to effort—in contrast to dollars—that has been put forth in US R&D. The “technical man” is the professional scientist or engineer with his supporting technical, administrative, and housekeeping staffs and his machines and equipment, i.e., the man plus the overhead costs. Two questions are of continuing interest: first, how much the cost per technical man has increased owing to all causes during the last 45 years, and second, how this has affected the actual R&D effort.

The revolution in technology sparked by the military requirements of WWII has markedly increased the equipment demands of the nations' laboratories and provided a means for an actual and further potential increase in output per technical man-year. In nuclear science, cyclotrons and bevatrons have followed in the wake of years of scientific research. In mathematics, still the lowest-cost area in scientific research, million-dollar computers have replaced many 5-cent pencils. The costs in R&D vary with the requirements of the scientific discipline being pursued. For example, in the US Air Force's continuing analyses of its basic research projects, costs per technical paper published in the nation's scientific literature vary from over \$100,000 per paper produced in the field of aeromechanics research to approximately \$10,000 per paper in the field of mathematics, in which original work can still be done with a minimum of equipment.⁷⁻⁹ An index based on the broad spectrum of R&D cannot delineate such variations in fine detail. However, a balanced mix of R&D specifying an average cost per technical man-year does identify relative levels of the technical effort supported in R&D.

The technical-man-year cost used in this paper is derived by dividing the total annual cost of each particular R&D organization participating in this study by the number of scientific and technical personnel working in the organization. Annual costs generally are based on equipment and operating expenses including rent; they exclude capital investments except for annual depreciation charges. To obviate the pitfalls of the imprecise accounting methods in R&D, the cost-per-technical-man-year data are translated into individual organization indexes that are consistent within the limits of each organization's reporting system. When the cost-of-research index is based on these individual series of relative values, the index itself has a high level of consistency.

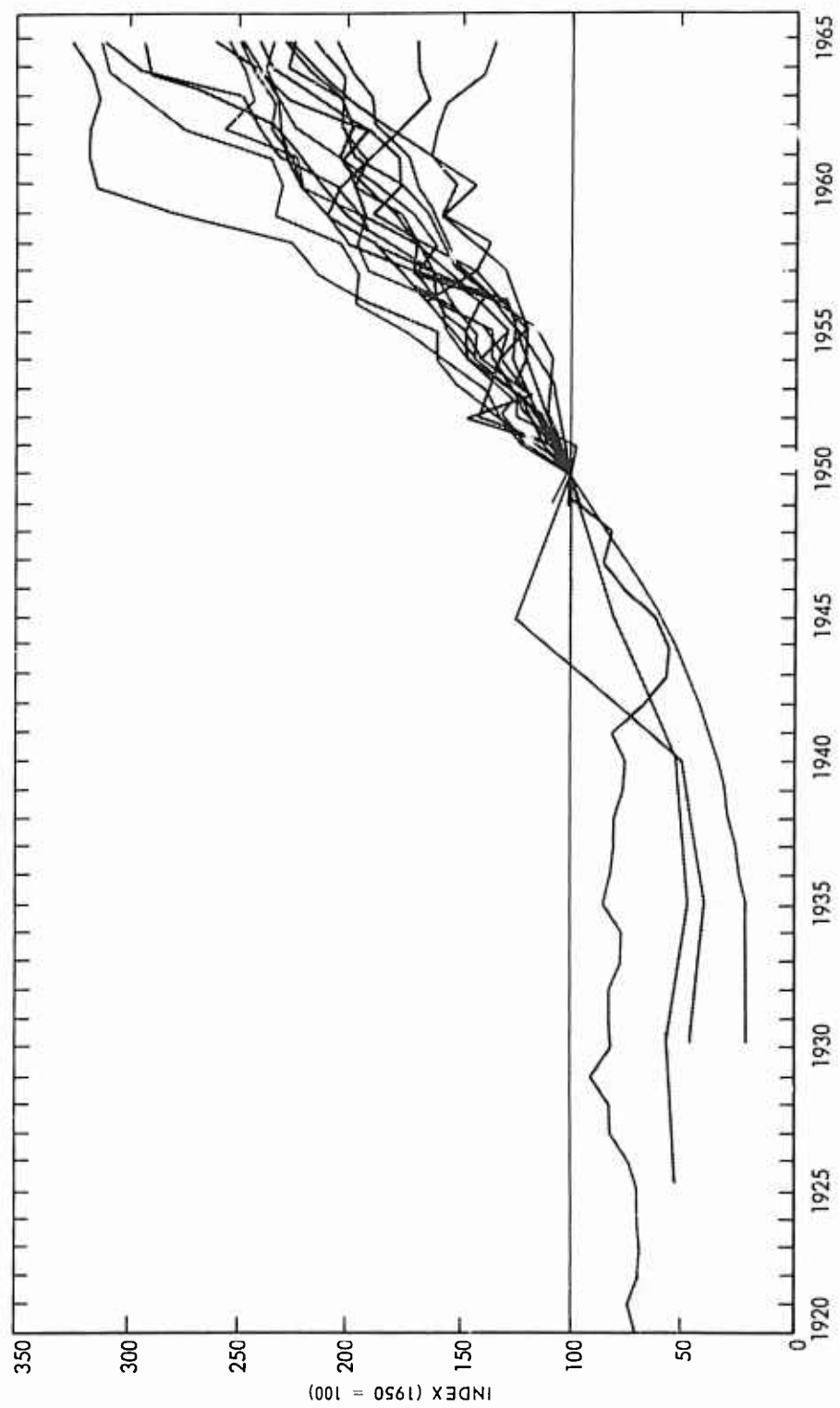


Fig. 1—Indexes of R&D Cost per Technical Man-Year for 17 Organizations, 1920–1965

Participation of Organizations

The index is based on 17 individual research organizations, ranging from the most sophisticated industry and foundation R&D enterprises to relatively small private and government laboratories and R&D divisions. Each was selected because its primary mission was in a representative field of research or R&D. The total is divided about equally among industrial, private nonprofit,* university-contract, and Federal organizations. The data coverage for individual organizations varies in time for first reporting from 1920 to 1950. Subsequent reporting continued through 1965, with the 1965 totals representing calculated annual figures based on 8 or 9 months of experience. The concentration of initial reporting in 1950 reflects in part the initiation of R&D agencies following WWII. It also reflects techniques of bookkeeping. Old records were found to be quite consistently uninformative on personnel classifications. One of the organizations, renowned for years in the R&D field, simply could not derive the numbers of professional and technical personnel from its existing records for years prior to 1950.

Fortunately several large R&D establishments canvassed detailed ancient records and did obtain data warranting the identification of the index trend back to 1920. The WWII era was one that led to extreme variations in R&D accounting systems, partly because of the abnormal aspects of wartime research. Government contracts, shifts in work and personnel assignments, and general speedup caused interesting repercussions in the personnel-cost relation. Note in Fig. 1 the almost-counterbalancing upswing and downswing of two of the old-line R&D organizations in the WWII period.

Individual and Group Indexes

Figure 1 presents the indexes of individual costs per technical man-year for the organizations cooperating in this study. The pattern represents a cross section of the R&D field in terms of type of sponsorship and size of organization. This includes industrial, Federal government, university-contract, and private-nonprofit groups. In actual costs per technical man-year by group the percentage increase from 1950 to 1965 ranges from 123 to 176. With the exception of the university-contract organizations, this range of increase over the 15-year period is less than the variations within the individual groups. The consistency in cost increase is indicated in Fig. 2, which identifies the cost-per-technical-man-year index for each of the groups, with the average superimposed.

Cost-of-Research Index

The long-term trend in national R&D costs per technical man-year is shown in Fig. 3. This is based on data for the participating organizations for the period 1930-1965, with extrapolations supplementing the data for the period 1920-1930 (see Fig. 1). The index values are presented in Table 1 for more convenient use.

*This classification for "industrial" and "private nonprofit" is that of the National Research Council.¹⁰

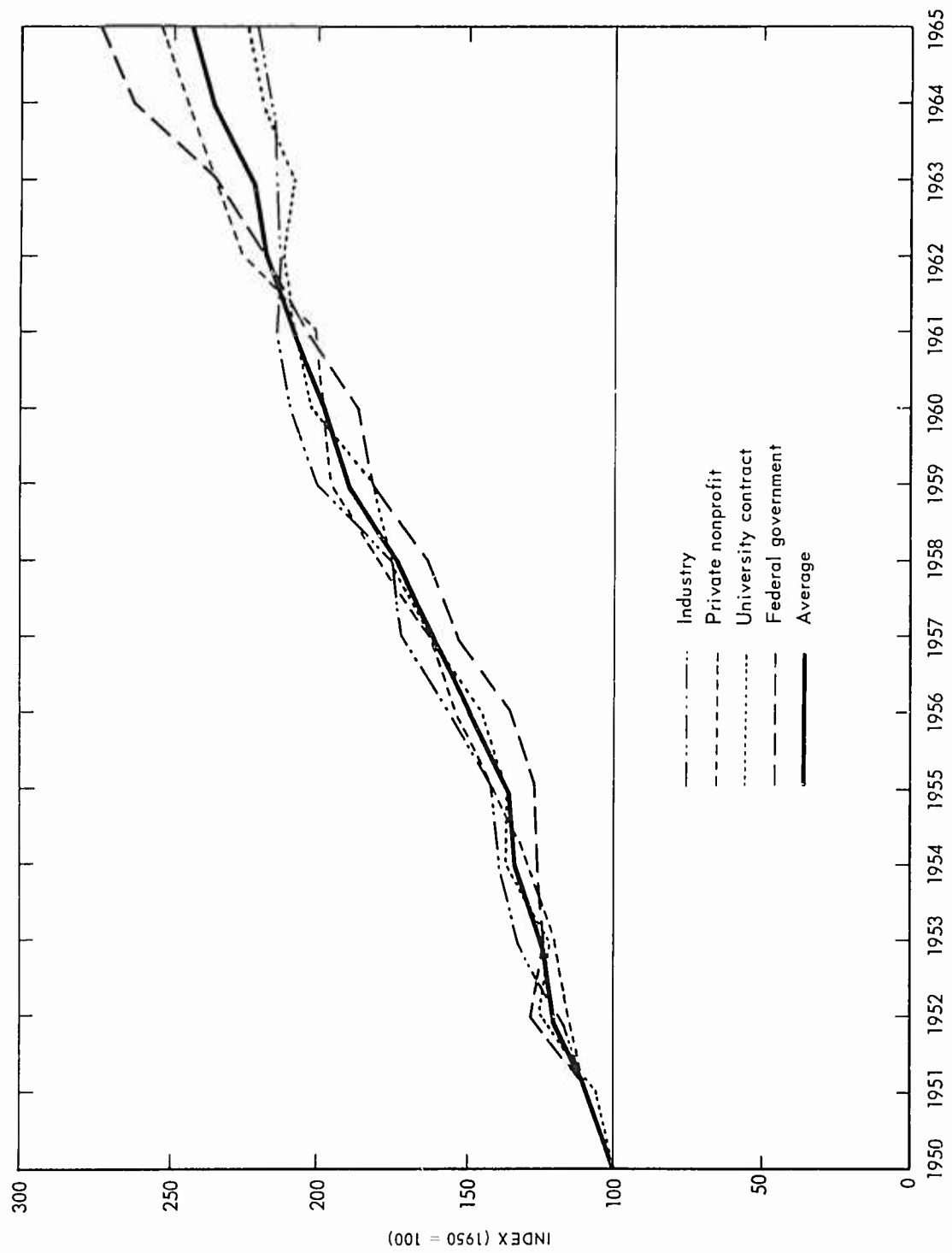


Fig. 2—Group Indexes of R&D Cost per Technical Man-Year, 1950–1965

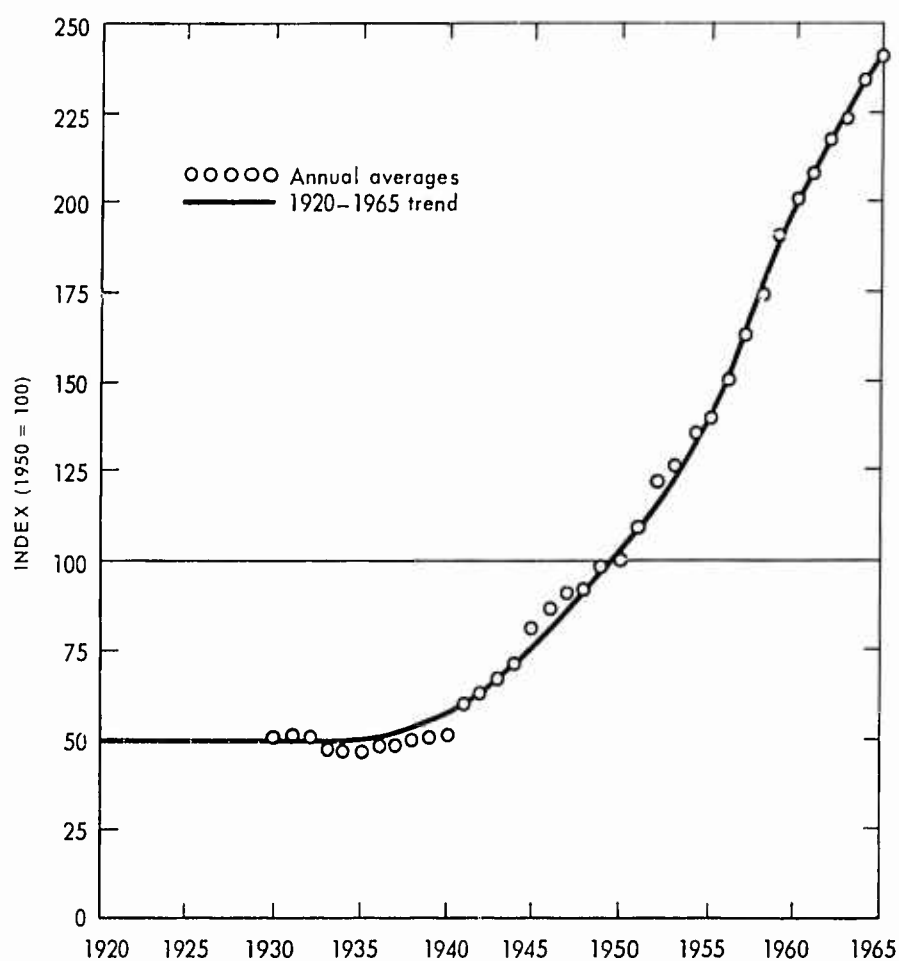


Fig. 3—Index of R&D Cost per Technical Man-Year, 1920-1965

TABLE 1
Index of R&D Cost per Technical Man-Year Based on Data from
17 R&D Organizations, 1920-1965
(1950 = 100)

Year	Index	Year	Index	Year	Index	Year	Index	Year	Index
1920	50	1930	51	1940	52	1950	100	1960	201
1921	50	1931	51	1941	60	1951	109	1961	208
1922	49	1932	50	1942	62	1952	122	1962	218
1923	48	1933	47	1943	66	1953	126	1963	224
1924	49	1934	46	1944	72	1954	135	1964	235
1925	49	1935	47	1945	80	1955	138	1965	242
1926	50	1936	48	1946	86	1956	150		
1927	52	1937	48	1947	90	1957	164		
1928	52	1938	50	1948	92	1958	174		
1929	54	1939	50	1949	99	1959	191		

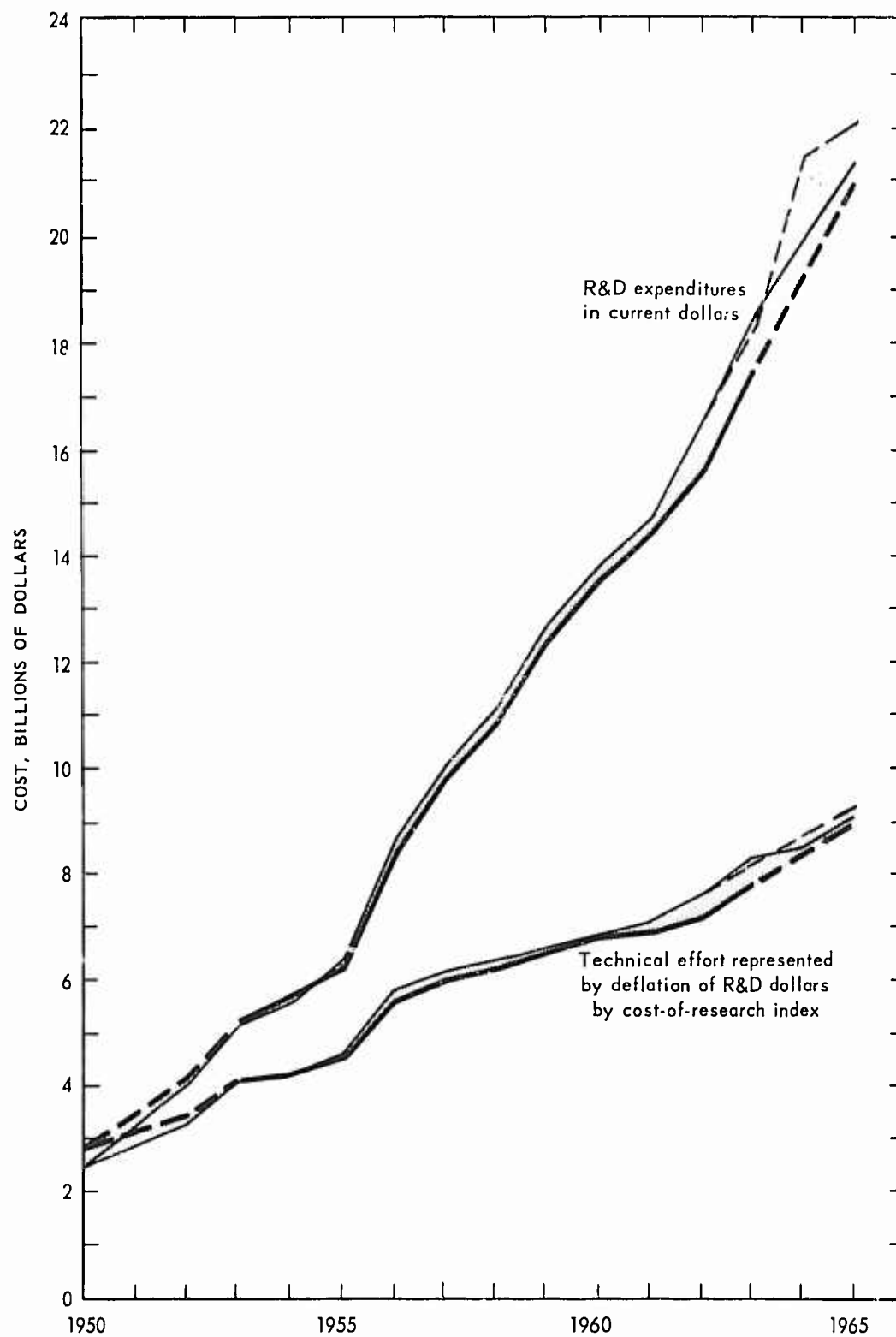


Fig. 4—US R&D Expenditures and Technical Effort, 1950–1965²⁻⁶

— National Science Foundation — Estimated
 — Industrial Research — Battelle Memorial Institute

R&D Dollars and Effort

In Fig. 4 the index of cost per technical man-year is applied to the estimated dollars expended in US R&D during the years 1950-1965.²⁻⁶ In 1965 the national economy invested eight or nine times as many dollars in R&D as in 1950. The increase in technical-man-year effort, as derived by the application of the index, is only three or four times the 1950 figure—an indicated increase in effort of slightly less than half the comparable dollar increase. The unmeasurable aspect, it must be noted, is the gain in effectiveness of technical-man-year effort resulting from ever-increasing numbers and types of scientific and technical aids, such as computers, introduced in R&D operations.

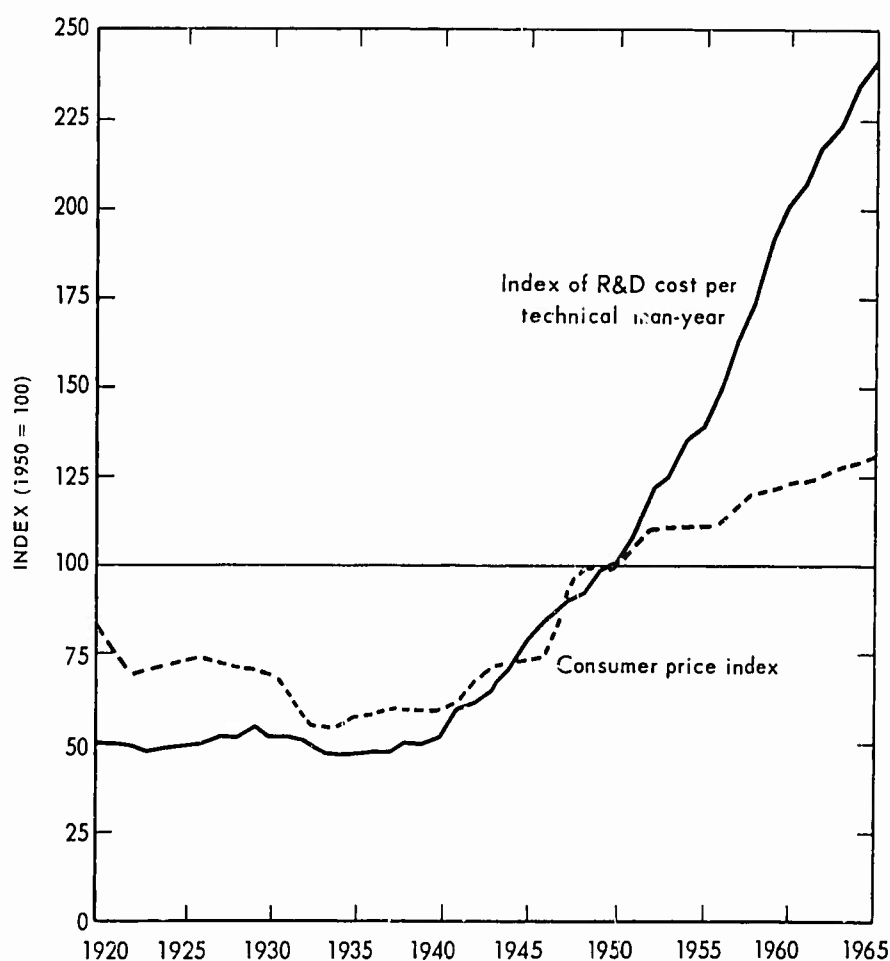


Fig. 5—Index of R&D Cost per Technical Man-Year and Consumer Price Index, 1920-1965

Perhaps the high rate of increase in R&D technical-effort costs in the past 15 years can be most sharply appreciated when it is compared with the cost-of-living index.¹¹ For comparison of the value of the R&D dollar and the take-home dollar the two indexes are shown in Fig. 5. Although the consumer's dollar in 1965 (based on January-November 1965) would purchase 76 percent of the amount it would in 1950, the R&D dollar would purchase only 41 percent of the technical effort.

TABLE 2
R&D Scientific and Technical Personnel, by Group

Group	1954				1958				1961				1965	
	US ^{a, 12}		17 organi- zations		US ^{a, 12}		17 organi- zations		US ^{a, b, 12}		17 organizations		US	17 organi- zations
	Number	%	Number	%	Number	%	Number	%	Number	%				
Total	223,000		21,000		326,000		25,000		411,000		na ^c		na	30,000
Industry	74		68		73		70		74					66
Federal government	13		17		12		15		11					14
Colleges and universities	11		8		13		8		13					8 ^d
Other nonprofit organizations	2		7		2		7		2		na		na	12 ^d

^aExcludes social scientists and psychologists.

^bThe most recent NSF survey encompassing all four segments of R&D sponsors.

^cNot available.

^dThe university-contract percentage was reduced from probably 9 percent to 8 percent of the total and the private nonprofit percentage increased from 11 percent to 12 percent as a result of the transition from The Johns Hopkins University Operations Research Office to the private nonprofit Research Analysis Corporation in 1961.

Professional R&D Personnel by Sectors

The most significant classification of organizations in terms of costs per technical man-year is related to how much research is being carried on and by whom it is being done. The annual volume of R&D is indicated in Fig. 4, in terms of both dollars and effort. Table 2¹² provides a general pattern of employment of scientists and technical personnel in R&D both for the US and for the organizations participating in this study. The disparity in timing for the recent data, as reported here, is obvious: 1961 is the most recent date for which the National Science Foundation (NSF) has data encompassing all four sectors of R&D employment—industrial, Federal government, university contract, and private nonprofit.

In coverage the US data are limited to full-time equivalent scientists and engineers and exclude social scientists and psychologists. The 17 cooperating organizations were requested to report their "scientific and technical personnel" and, by definition, did include social scientists and psychologists. On the basis of the figures in Table 2, the sample group represented approximately 9 percent of the total scientific personnel in the US R&D in both 1954 and 1958. Based on 30,000 scientific and technical personnel as a 9 percent sample in 1965, total US R&D personnel would total 333,000. But the reported NSF total for 1961 is 411,000. This by itself would imply that the personnel of the organizations cooperating in this study is increasing at a less rapid rate than the total US R&D scientific and technical population.

The pattern of distribution among the four sectors in the US total and the sample group is relatively consistent for the industry, Federal government, and college and university sectors. An index of cost per technical man-year of R&D actually carried on in the US was obtained by applying the NSF group percentages of performers in R&D to the data for comparable groups within the 17 organizations under study. This indicator of national R&D cost per technical man-year follows so closely the average of the group index shown in Fig. 2 that there is no need to present it separately.

"Theoretical" and "Development" R&D Costs

The R&D organizations that emphasize theoretical research tend to be among the smaller organizations and in the lower-cost area. Those that encompass large-scale development operations tend to fall in the larger-sized groups and higher-cost brackets. Classifying the organizations into the nebulous categories of "theoretical" and "development," the number of organizations in the two groups are approximately equal. The increase in cost per technical man-year from 1950 to 1965 for the research-oriented group is 134 percent and for the development-oriented group is 151 percent. The index of cost per technical man-year for each of the two groups is shown in Fig. 6.

Equipment Costs

It is certain that the cost relation hinges in part on equipment requirements and costs. Admittedly it is difficult to estimate the increased requirements for the various types of laboratory equipment, which is a significant factor particularly in development-oriented costs. It is even more difficult to estimate the increasing volume and the R&D costs in the specialized area of auto-

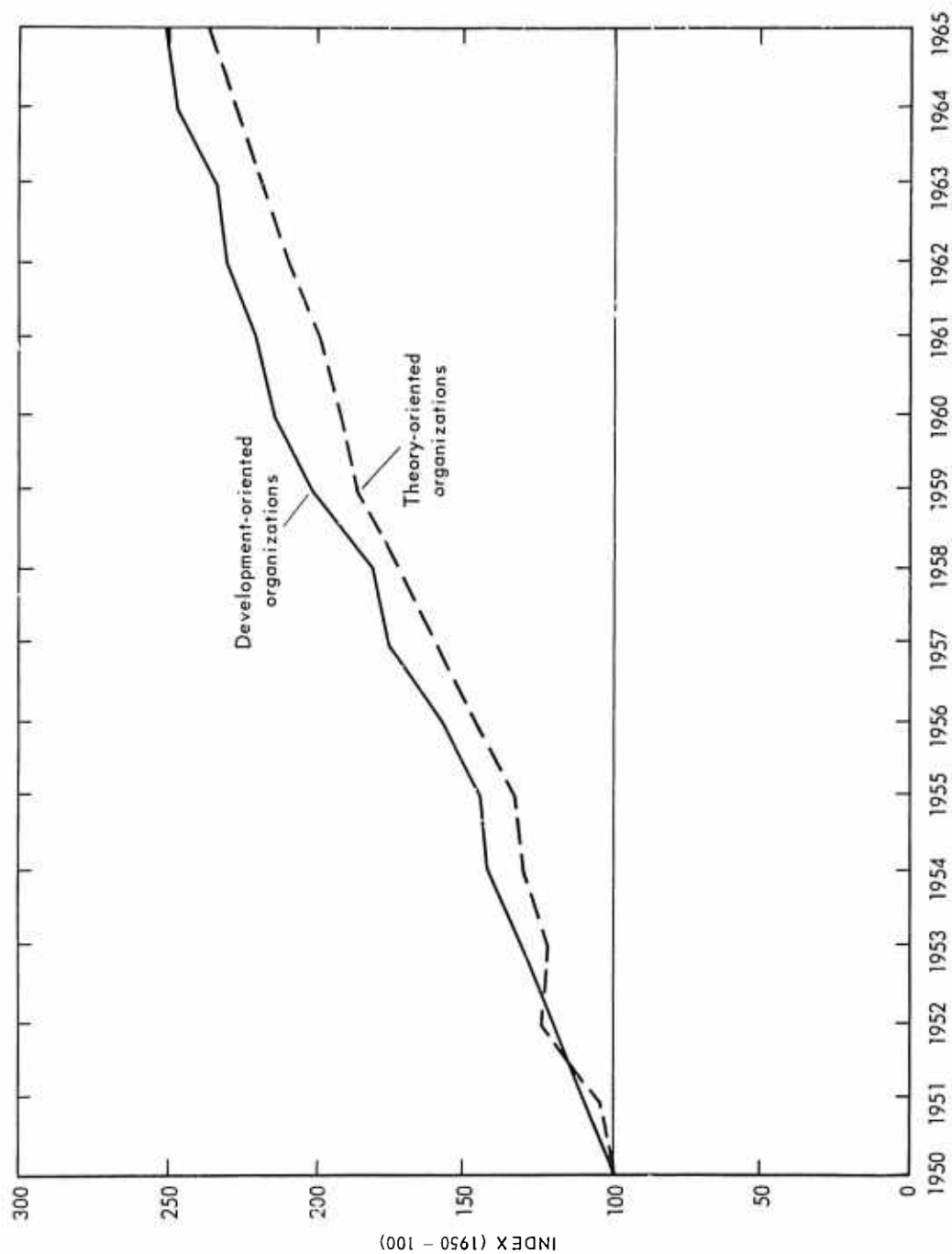


Fig. 6—Indexes of R&D Cost per Technical Man-Year for Theory-Oriented and Development-Oriented Organizations, 1950–1965

matic data processing (ADP), for which equipment was first available commercially in the early 1950's and which now is an integral part of any study dependent on large volumes of data. An estimate of computer applications in the major US economic sectors in 1963-1964¹³ identified the extensive and varied uses of ADP, including R&D data processing, in the Federal government. In the manufacturing segment of the economy more than 35 percent of US firms utilized ADP in their R&D programs. Between 10 and 35 percent of the service industries were identified as users of ADP in R&D data processing, and a potential for considerably greater use was noted.

Professional Scientific Salaries

A major contributing element in the national upswing in R&D costs throughout the past 15 years has been the increase in salaries of scientific and professional personnel. The annual national surveys of the Los Alamos Scientific Laboratory¹⁴ have not only identified the general upward trend but also have indicated patterns of emphasis. These surveys include the salary distribution for professional scientific personnel by number of years since graduation. The salary indexes for nonsupervisory personnel classified by "age" groups (0-4 years, 5-9 years, 10-14 years, and 15-42 years from graduation), together with the weighted index based on numbers within the groups, are shown in Fig. 7.

Salaries for all nonsupervisory R&D personnel have increased over the period 1950-1965 at an average annual rate of 5 percent. Compared with the 6 percent average increase during the 1950's, however, the average since 1960 has been 4 percent. The average increases for the four categories of nonsupervisory professional R&D personnel are presented by time periods in Table 3.

TABLE 3
Average Annual Increases in Salaries of Nonsupervisory
R&D Scientific and Professional Personnel,
by Years since Graduation
(In percent)

Time period	Years since graduation				
	0-4	5-9	10-14	15-42	Total
1950-1955	6	6	5	5	6
1956-1960	7	6	6	5	6
1961-1965	3	4	4	5	4

Whereas Fig. 7 identifies the levels of the salary indexes by age groups over the period 1950-1965, the group percentages for three 5-year periods presented in Table 3 point up the relative changes for the individual groups. These data indicate that the so-called "younger" scientists benefited from the highest proportional salary increases during the 1950's. During the first half

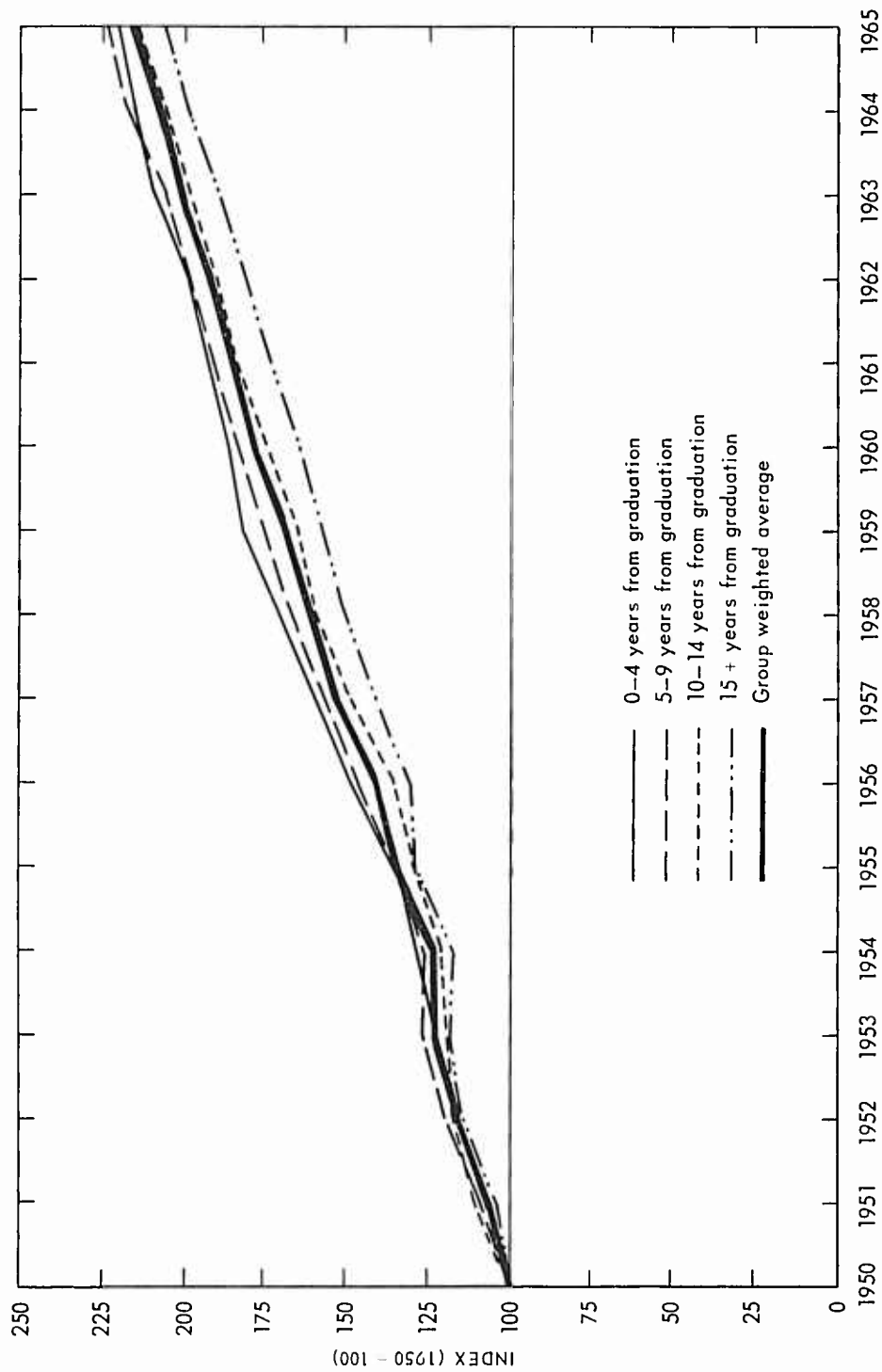


Fig. 7—R&D Salary Indexes according to Years from Graduation for Professional Nonsupervisory Personnel, 1950–1965, by Group

of the 1960's the "older" scientists—the group 15 to 42 years from graduation—had the highest annual percentage increase in salary.

Data for supervisory personnel in the comparable scientific age groups are available only for the years 1958–1965. The average increase for this segment of R&D personnel varies only slightly from that for the nonsupervisory personnel during the same 6-year period. The indication is that a 15-year index for total scientific and professional personnel would be approximately the same as the one shown for nonsupervisory personnel in Fig. 7. Among supervisory personnel, as would be expected in view of experience requirements, the greater salary increases are among the older age groups. There is, for example, no category of 0–4 years since graduation for supervisory personnel. Among the four groups reported on (5–9 years, 10–14 years, 15–19 years, and 20+ years) the highest single annual salary increase was 8 percent for the 5–9-year group between 1959 and 1960 compared with 5 percent for each of the other three groups in those 2 years. From 1961 through 1965 the category 20+ years from graduation has maintained the lead among supervisory personnel in annual percentage increases in salary with an average gain of 5 percent. The average annual increase for the 15–19-year group during the same period was 4 percent and for the groups 10–14 years and 5–9 years, 3 percent.

Index Trends, 1950–1965

The trend in the index of cost per technical man-year, as indicated in Fig. 8, has continued upward throughout the past 15 years. At present the R&D technical-man-year costs are increasing at the same general rate as R&D salaries and, as in the case of salaries, the current annual increases are lower than in the 1950's. The annual increases in technical-man-year costs from 1950 through 1965 average 6 percent. By 5-year periods the average increases are 7 percent for 1950–1955, 8 percent for 1956–1960, and 4 percent for 1961–1965.

The annual percentage increases from which the 5-year averages are derived are identified in Fig. 9. The general trend, however, is more readily observable in Fig. 10, in which the pattern is based on overlapping 3-year averages. Here the peak periods of high annual increases in technical man-year costs stand out—1951–1953 and 1956–1959. The plateau from 1960 to 1965 reflects the average annual increase of 4 percent for the 5-year period 1961–1965.

SUMMARY

The purpose of this paper was to provide a measure of the cost of technical man-years supported by R&D funds expended yearly in the US relative to the effort—in contrast to dollars—that has been put forth in US R&D. The cost-of-research index represents such a tool. It can identify the relative effort invested by years in terms of hours of work. It cannot differentiate between the levels of effectiveness of that effort. The augmentation by machines, for example, has increased the productivity of the average technical man-year to an unmeasured degree. The work-effectiveness aspect must be considered separately.

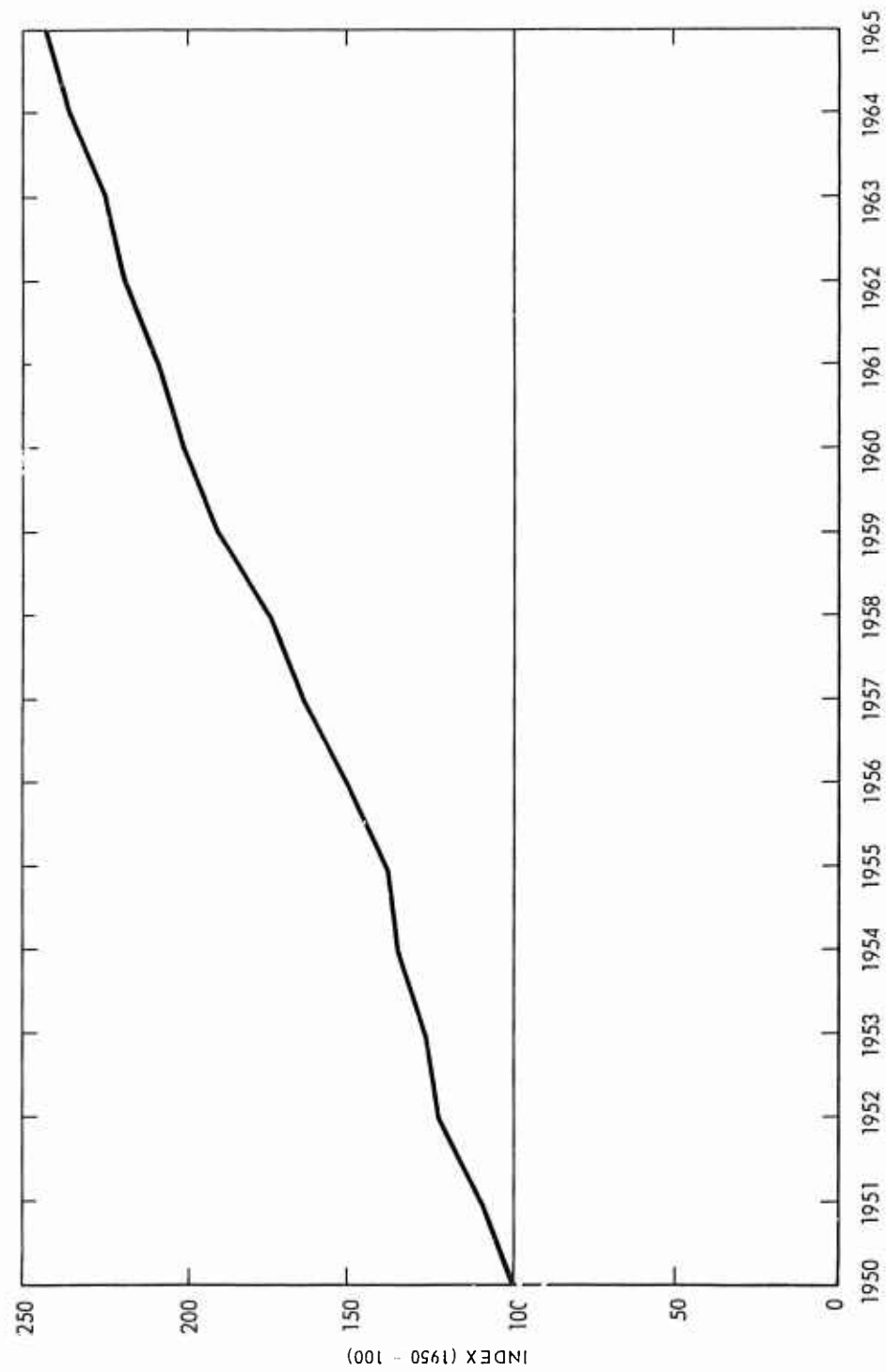


Fig. 8—Index of Cost per Technical Man-Year, 1950–1965

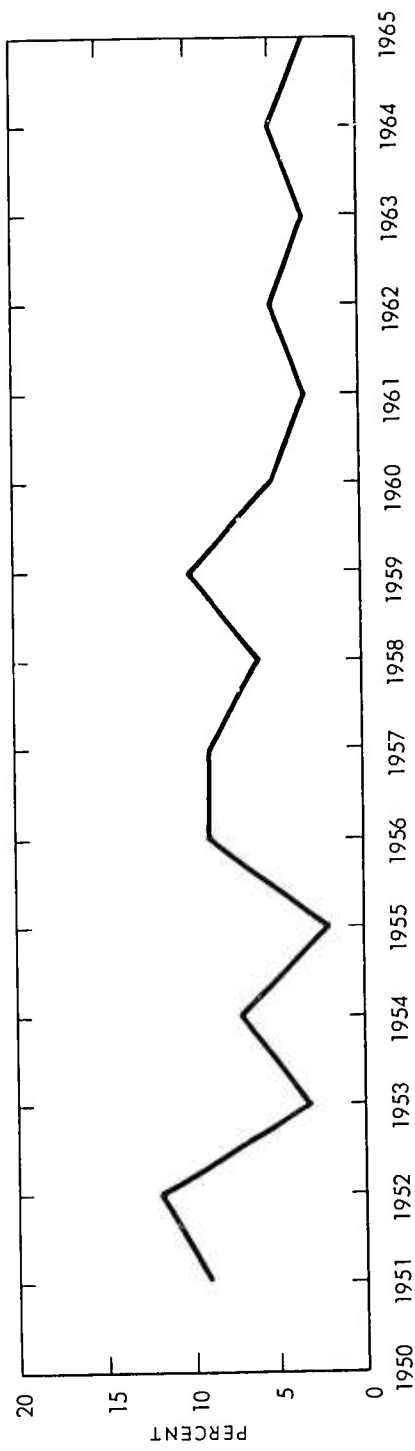


Fig. 9.—Cost per Technical Man-Year: Relative Increases Based on Annual Percentage Increases

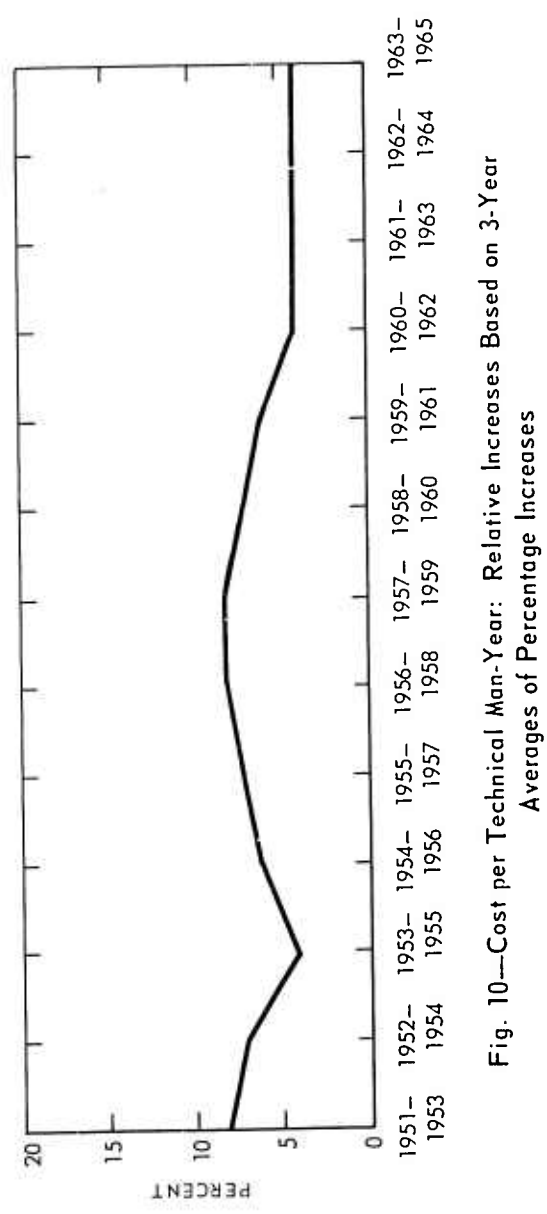


Fig. 10.—Cost per Technical Man-Year: Relative Increases Based on 3-Year Averages of Percentage Increases

This study leads to the following conclusions:

1. The average annual increases in technical-man-year costs were 7 percent for 1950-1955, 8 percent for 1956-1960, and 4 percent for 1961-1965. The average over the 15-year period is 6 percent. The appreciable decline in the rate of increase during the period 1961-1965 is readily apparent.
2. From 1950 to 1965 the annual R&D dollar totals increased from less than \$3 billion to about \$22 billion. During that period the actual man-years of technical effort, indicated by the application of the cost-of-research index to the annual dollar totals, increased at approximately half the rate of increase in funds expended.*
3. The index level of the Federal government was higher in 1964 and 1965 than that of industry, university contract, and private nonprofit organizations. It was the lowest of the four from 1954 through 1960. This reversal reflects effects of Federal salary and support programs designed to attain and maintain a fully competitive position in R&D.
4. The technical-man-year costs for development-oriented organizations continue higher than for theory-oriented organizations. The margin of difference is about the same in 1965 as in 1953.
5. With the upswing in R&D expenditures following WWII, the trend in salary increases in the 1950's favored the "young" professionals--the age bracket below 10 years from college graduation. In the 1960's the average annual percentage increase was highest for personnel 15 or more years from graduation. This may indicate an increase in emphasis on the experience and expertise of the older professionals.

Research and development is accomplished by the expenditure of manpower and dollars. All the approaches to planning and budgeting for R&D must be based on both technical manpower and dollars.

There has been a trend toward stabilization in the pattern of technical-man-year costs in the period 1961-1965. In view of the general trend upward, a tool such as the cost-of-research index should be used in future planning and budgeting for R&D with the precise intent to determine whether the trend of 1961-1965 has continued or whether the rate of change in the cost per technical man-year has varied markedly. The cost-of-research index used to develop the rates should be updated and applied on a recurring annual basis.

*By this measure, there were critical areas in military technology in which the absolute dollar support increased during the 1950's, but less actual effort was expended than in 1950.

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